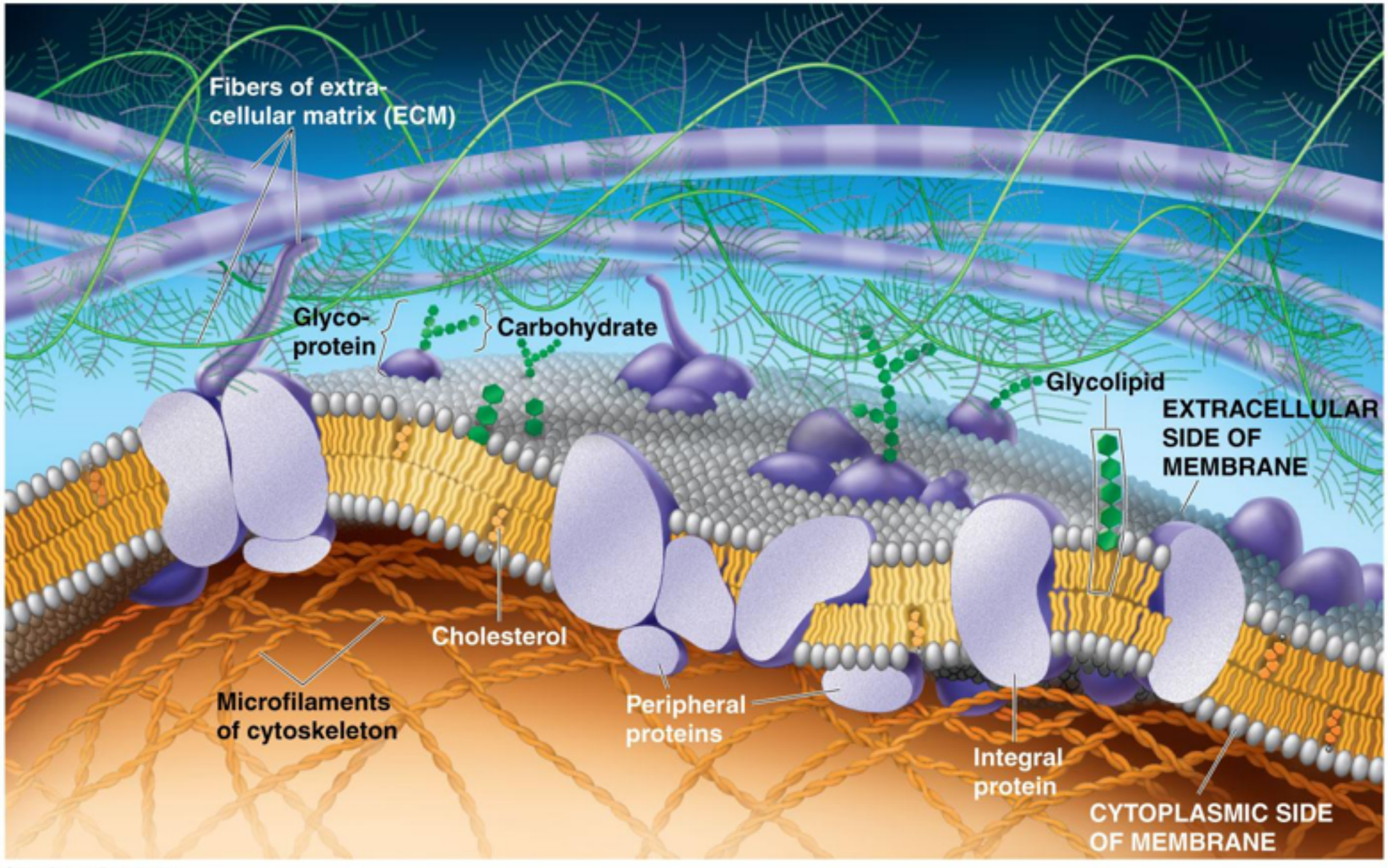
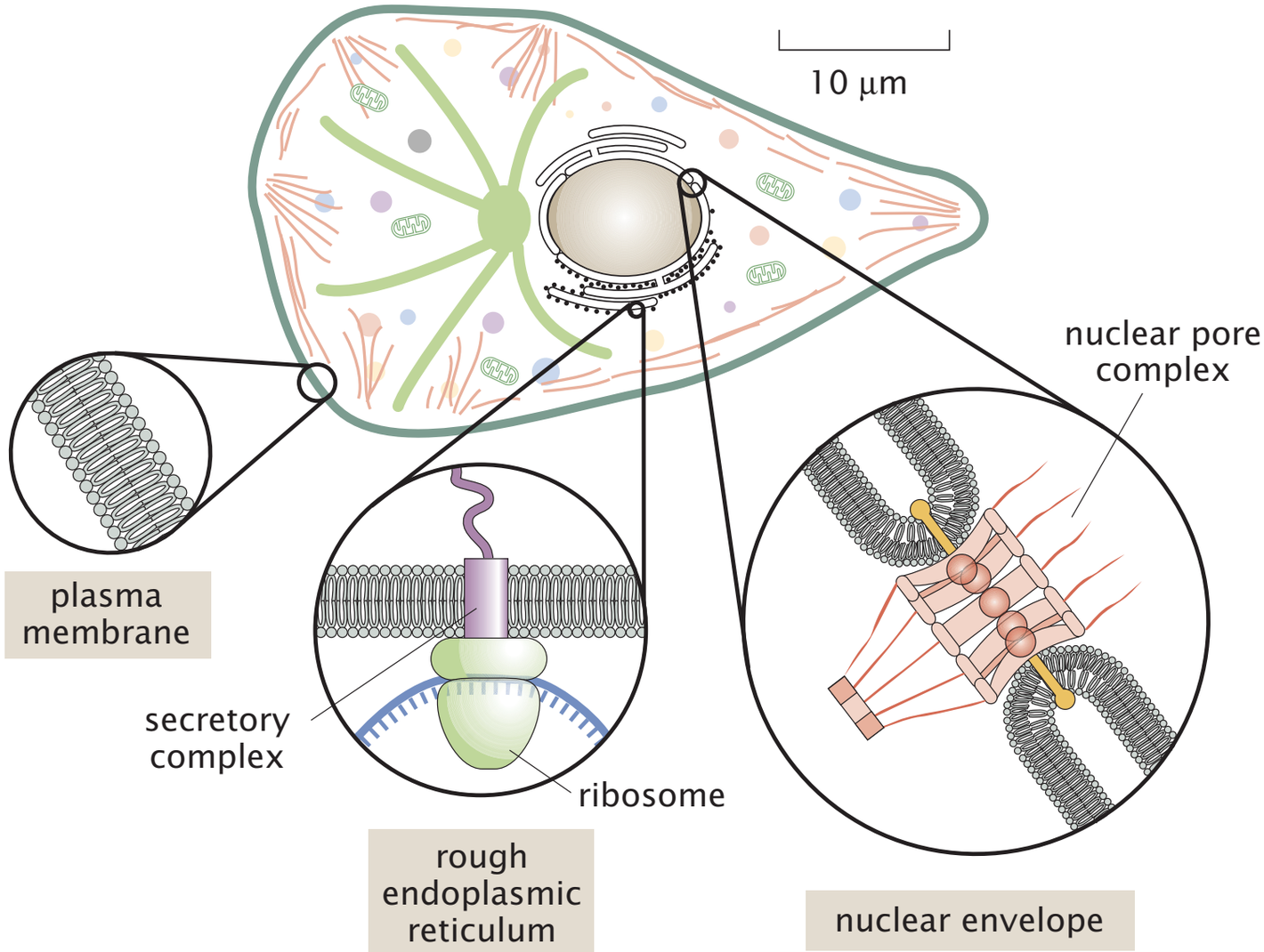
MAE 545: Lecture 14 (11/10)

Mechanics of cell membranes

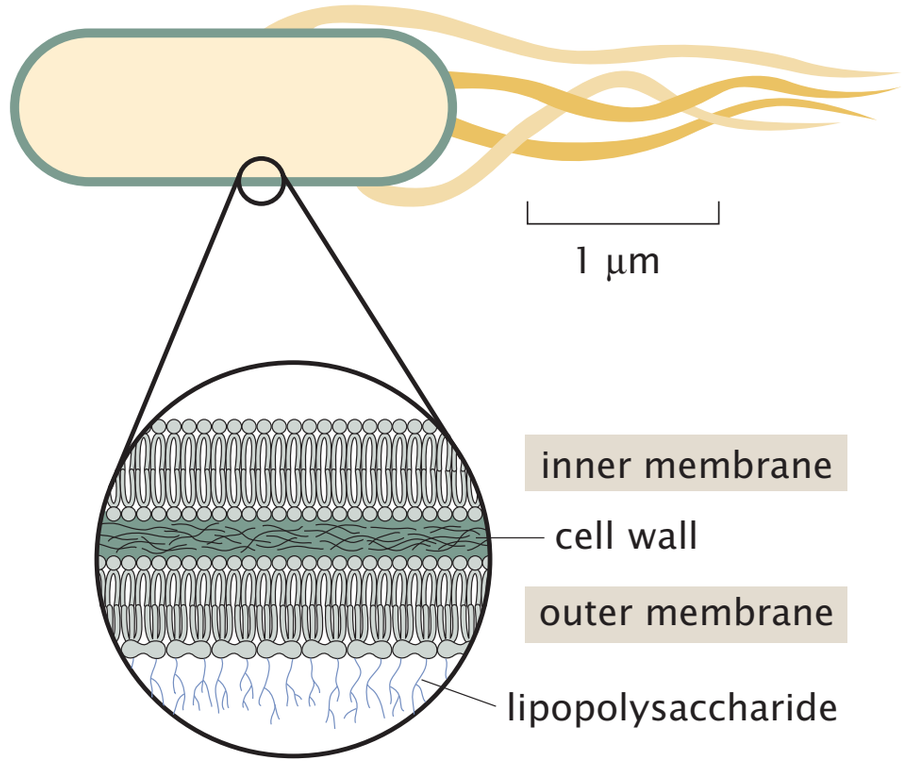


Cell membranes

Eukaryotic cells

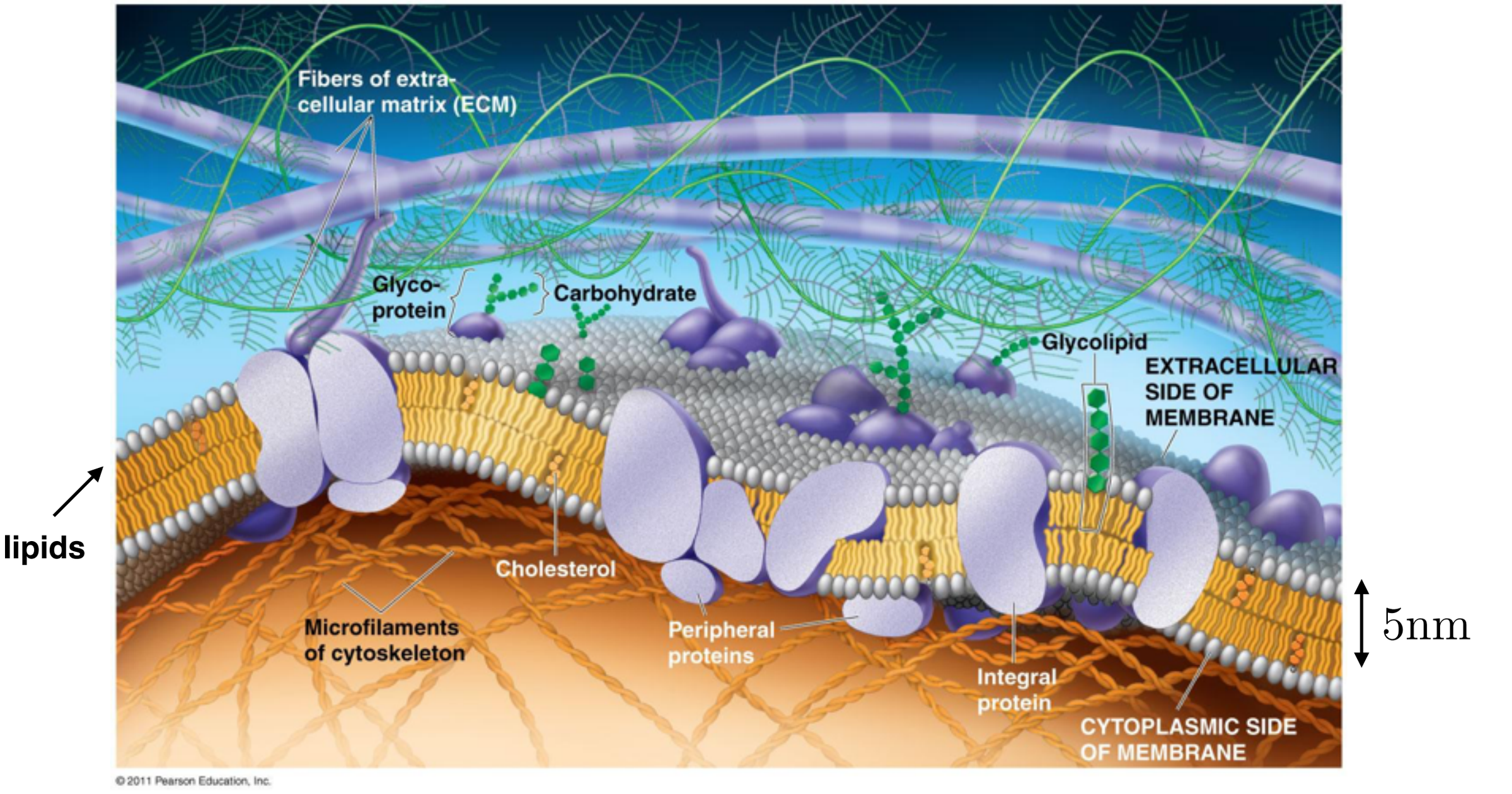


E. Coli

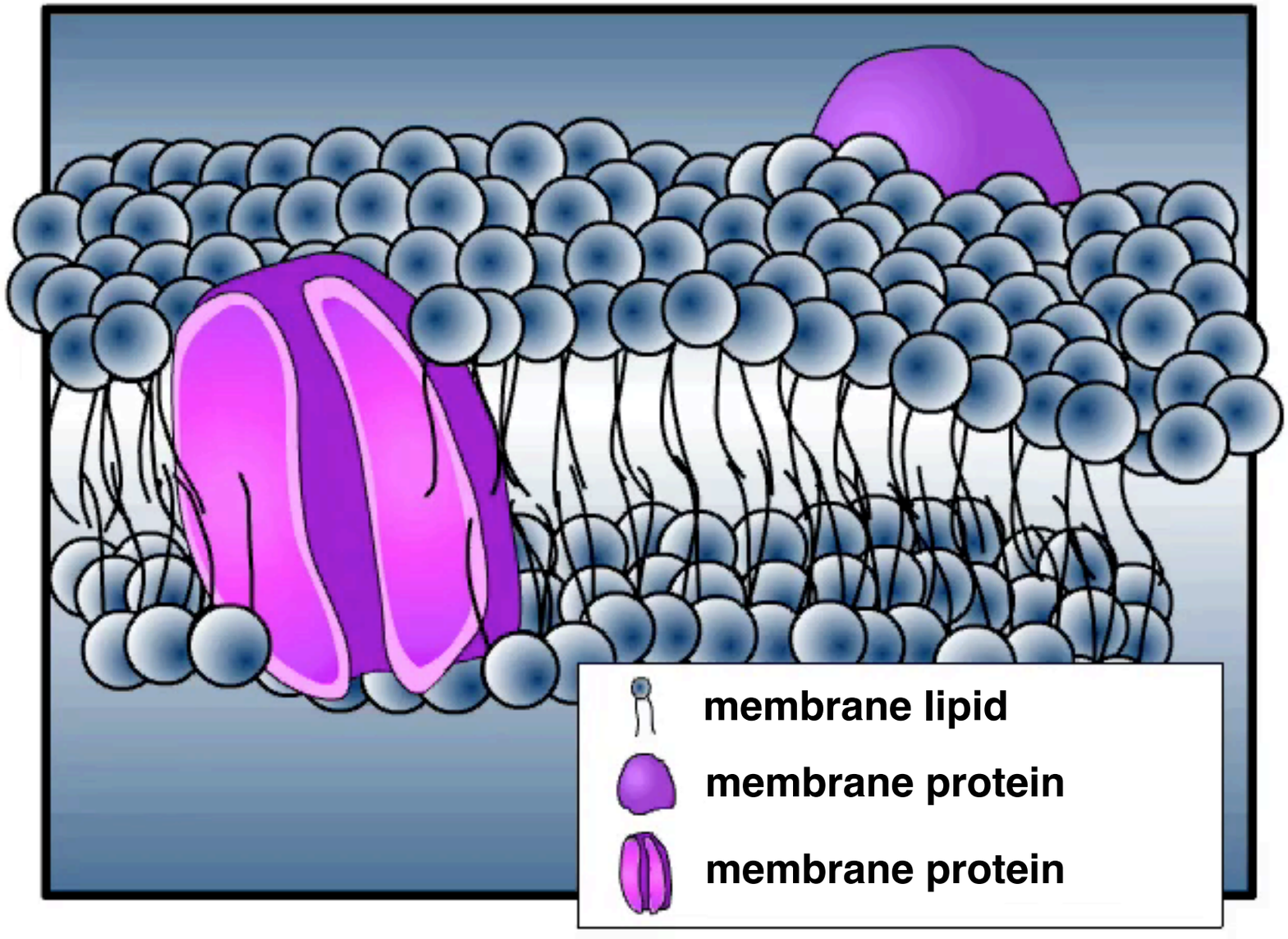


R. Phillips et al., Physical Biology of the Cell

Cell membrane



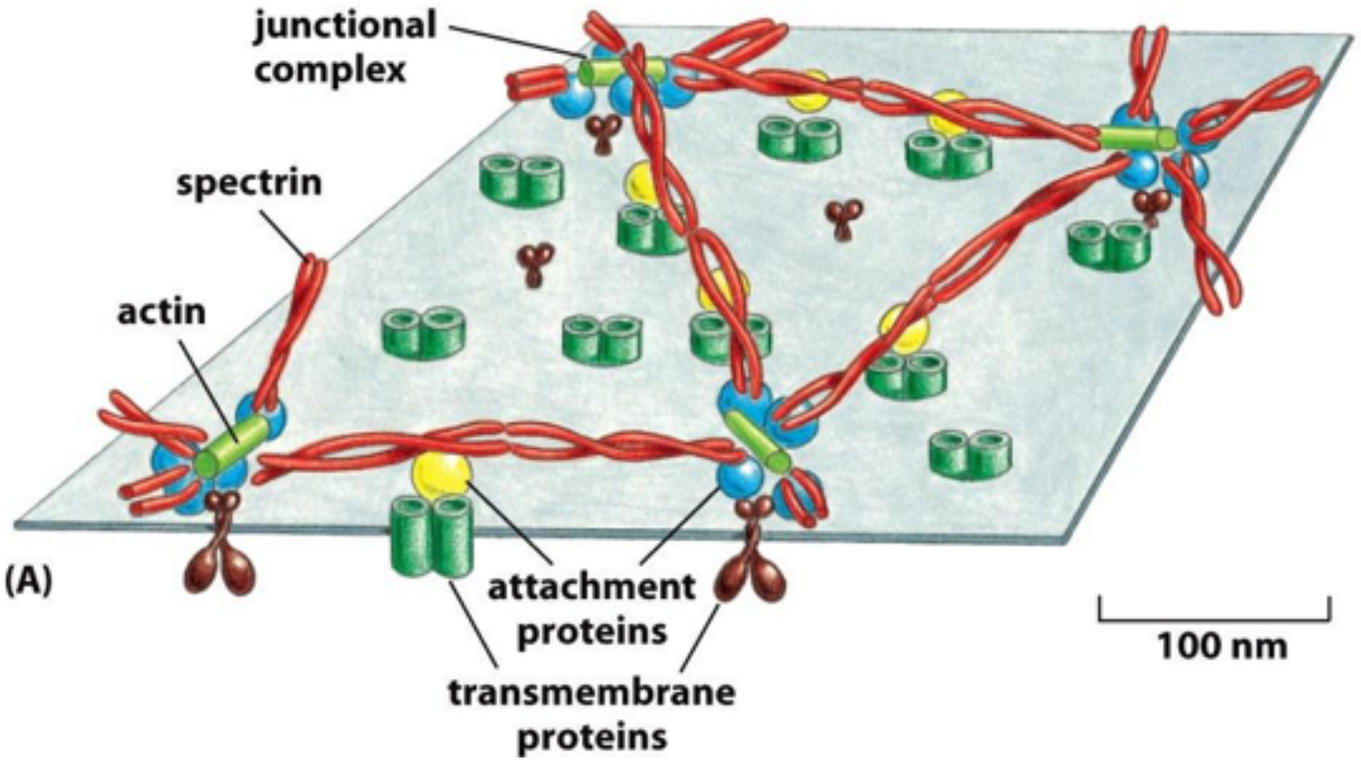
Lipid membrane behaves like fluid

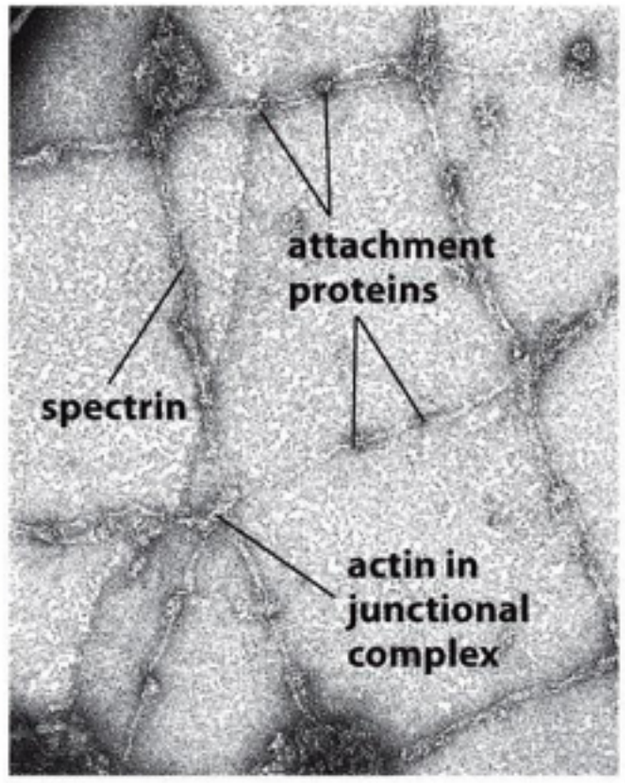


Lipid molecules and proteins can move around!

Flipping of lipid molecules between the layer is unlikely.

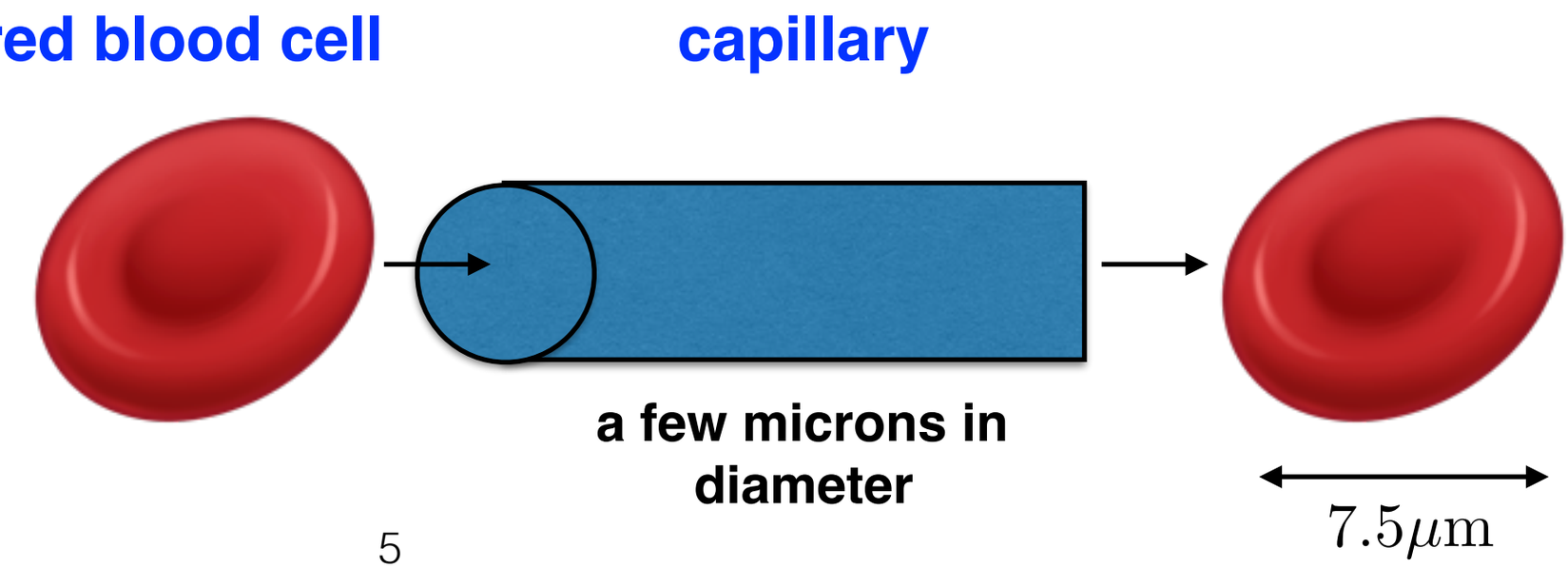
Membrane attached spectrin network provides solid-like behavior



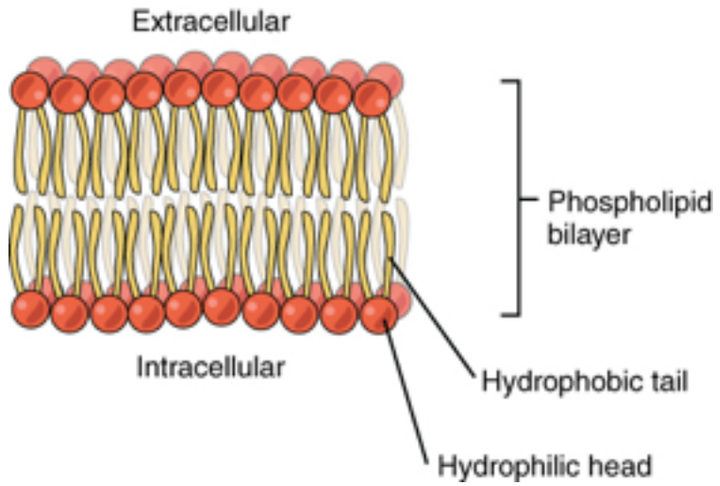


Spectrin network provides structural stability for cells

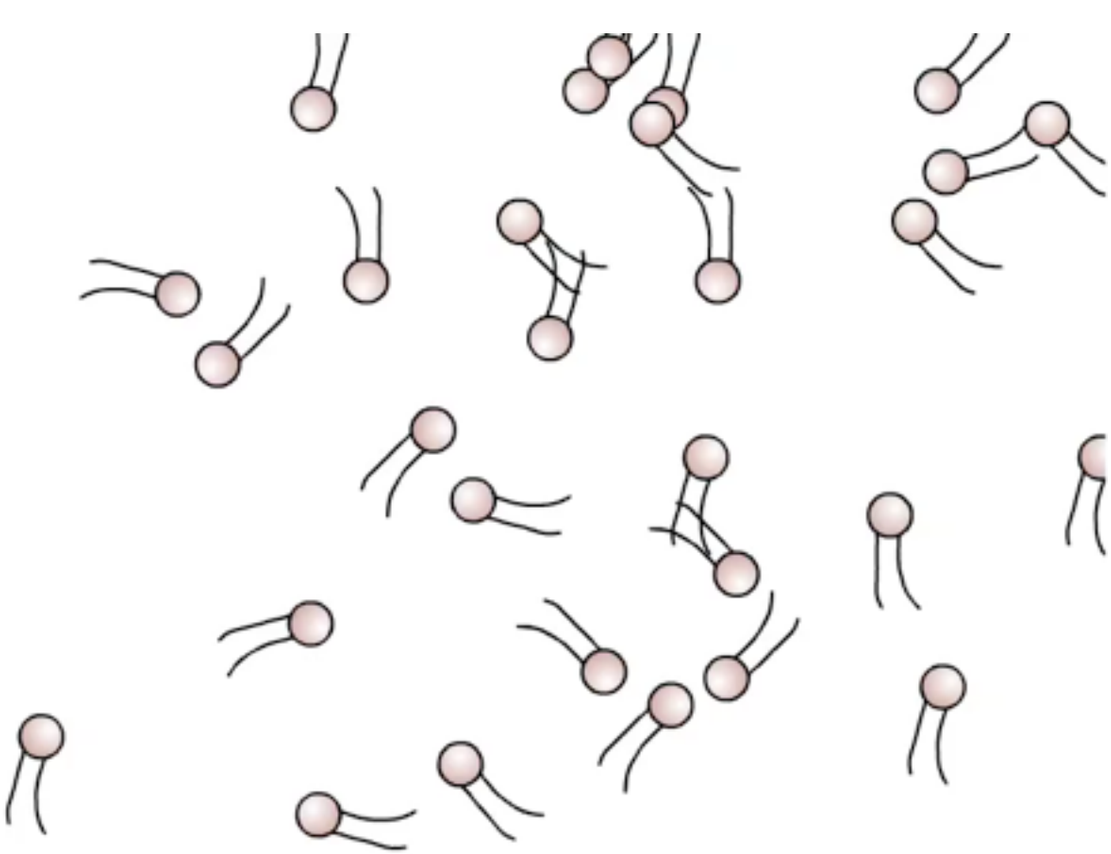
Alberts et al., Molecular Biology of the Cell

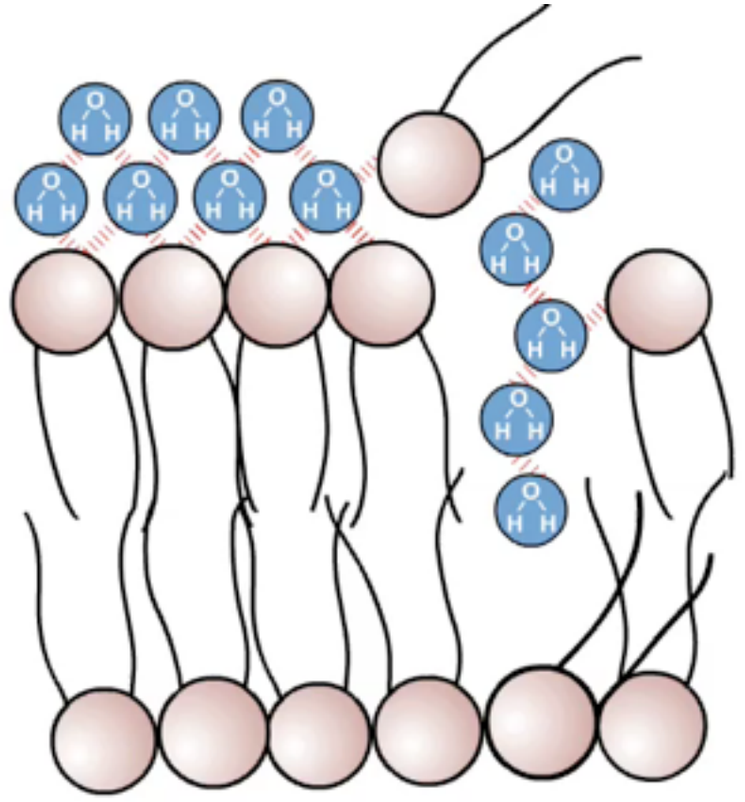


Lipid membrane



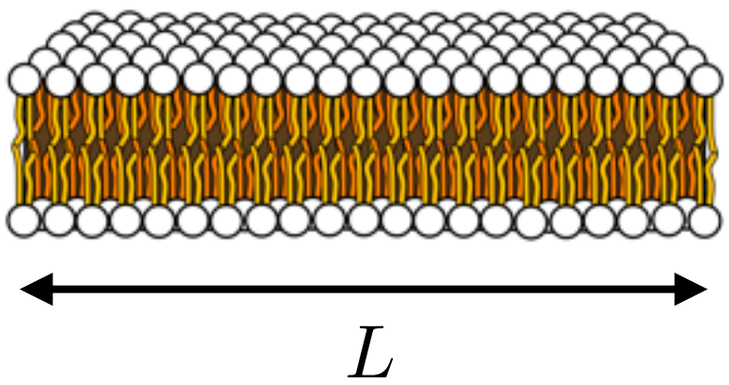
In water solution lipid molecules spontaneously aggregate to prevent undesirable interactions between water and hydrophobic tails.





Flat lipid bilayers vs lipid vesicles

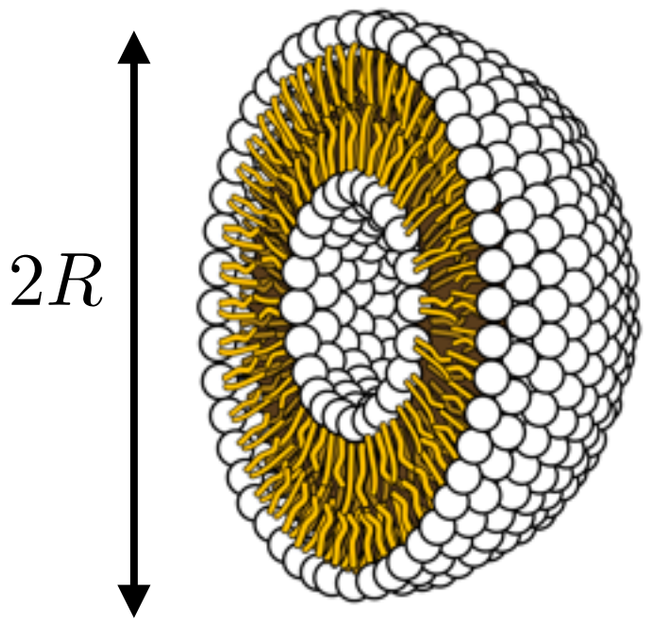
flat bilayer



energy cost on the edge between lipid tails and water molecules

$$E \propto L$$

vesicle

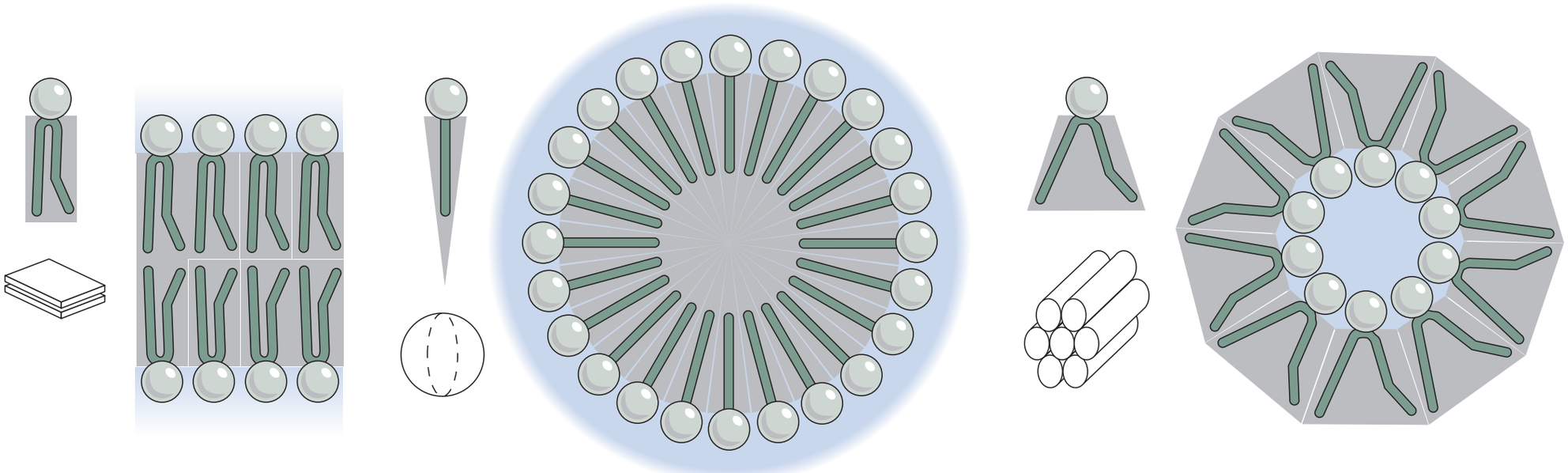


bending energy cost

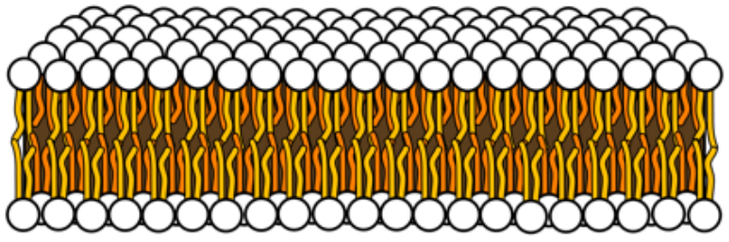
$$E \propto \text{const}$$

Large vesicles have lower energy cost then flat bilayers!

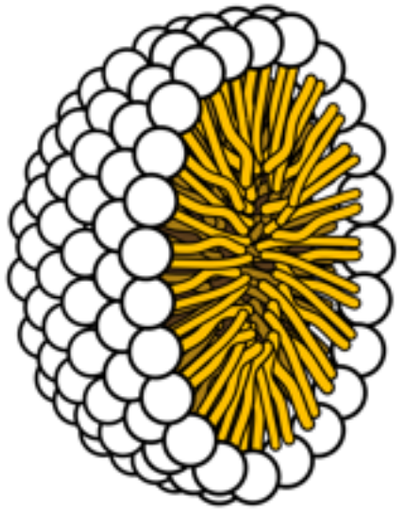
Shape of lipid molecules can induce spontaneous curvature of structures



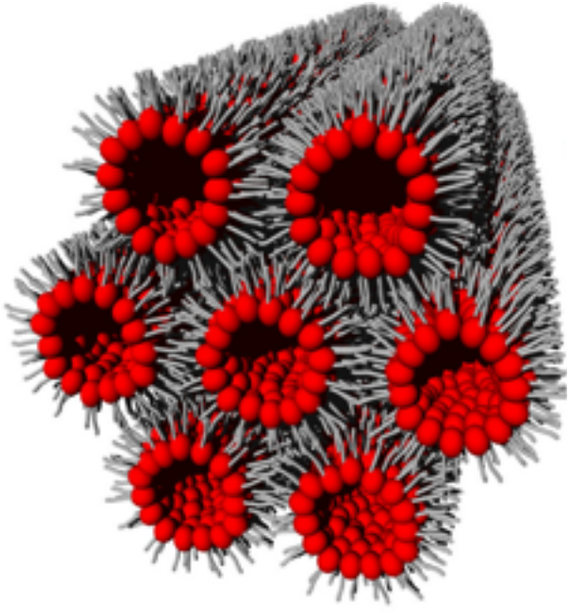
bilayer



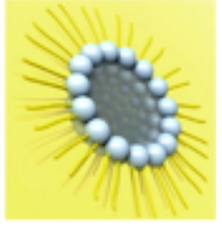
micelle



H-II phase

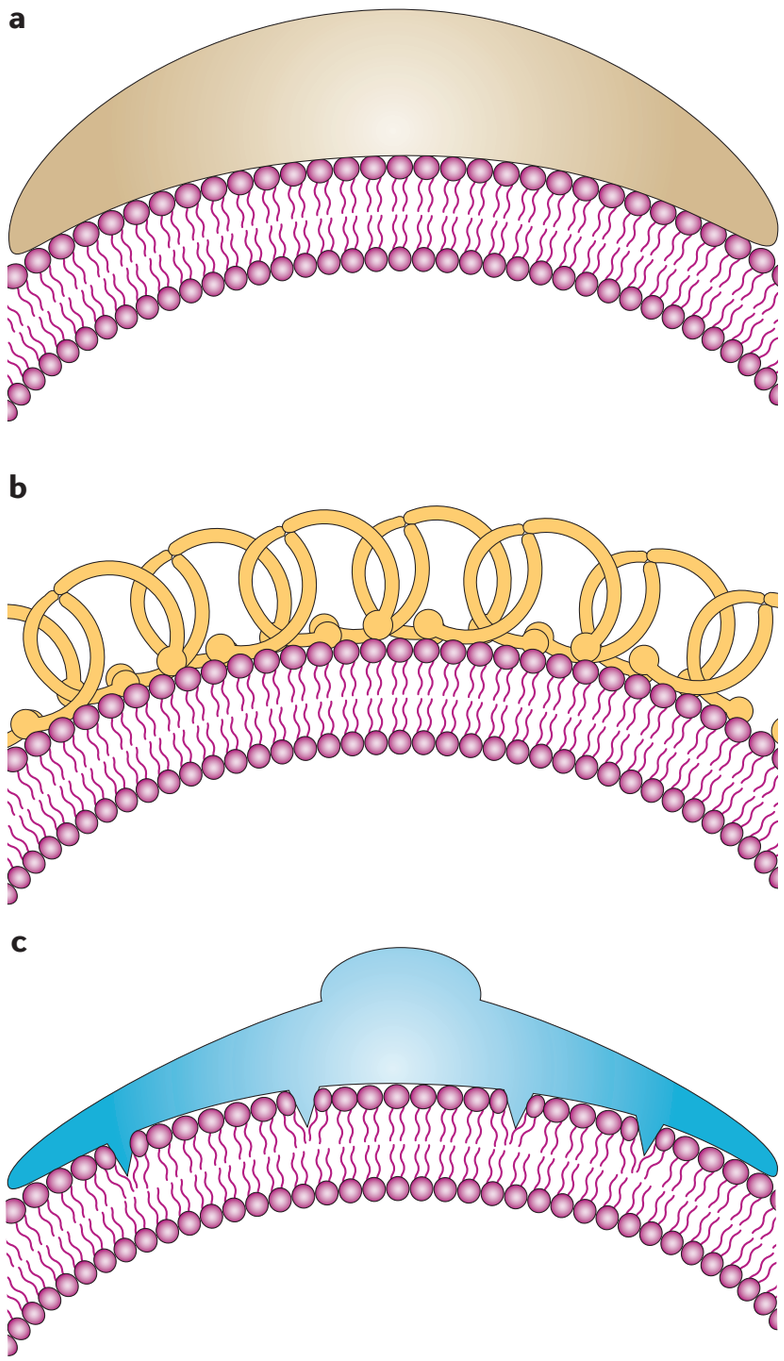


inverted micelle



R. Phillips et al., Physical Biology of the Cell

Membrane proteins can induce spontaneous curvature



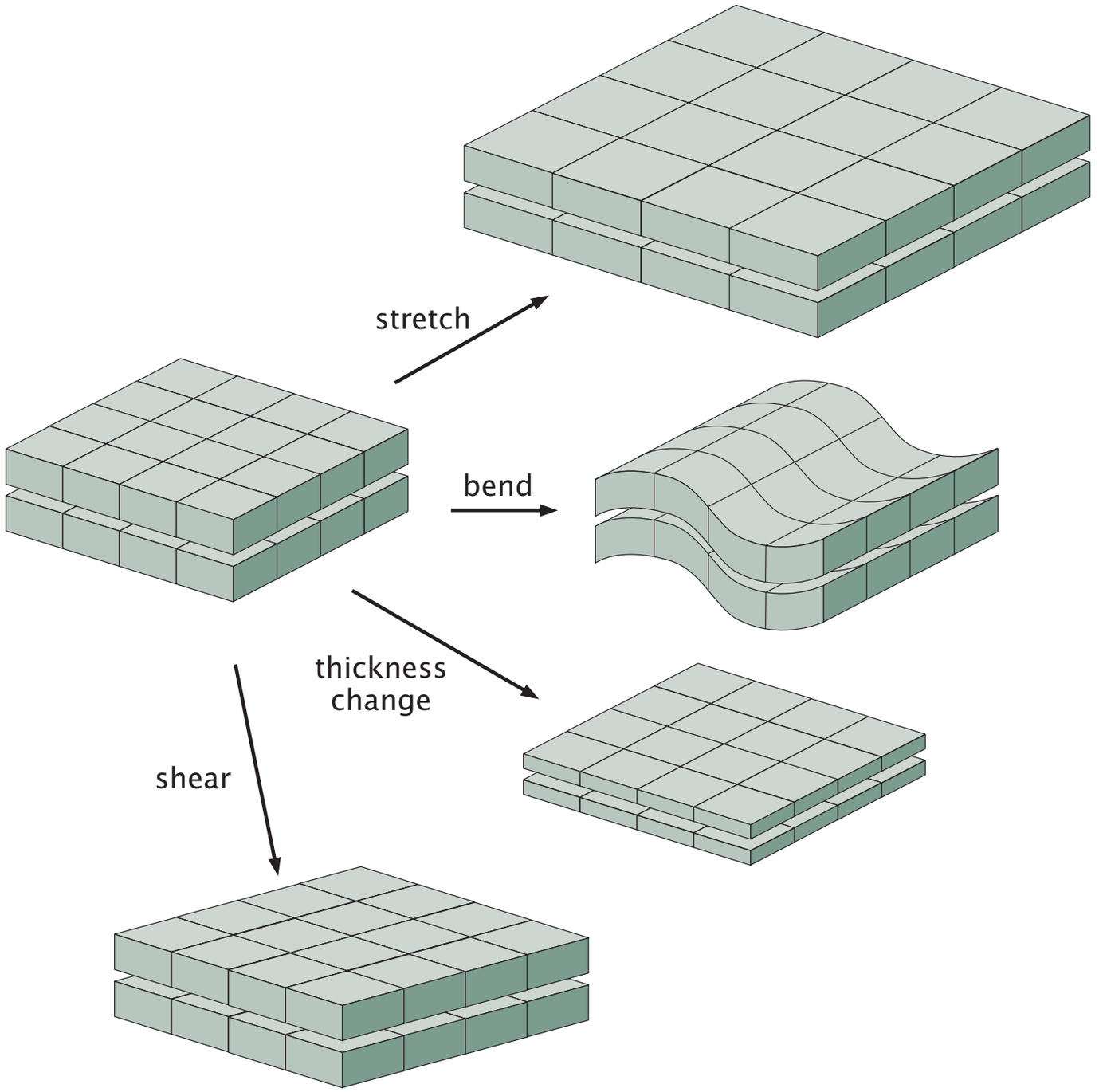
binding of rigid curved proteins

interactions between coat proteins bend the membrane

insertions of protein parts between lipid molecules on one side of the layer

J. Zimmerberg and M.M. Kozlov,
Nat. Rev. Mol. Cel. Biol. 7, 9 (2006)

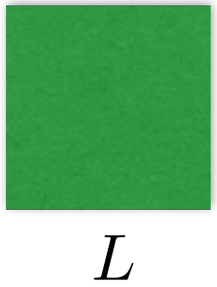
Membrane deformations



R. Phillips et al., Physical Biology of the Cell

Energy cost for stretching and shearing

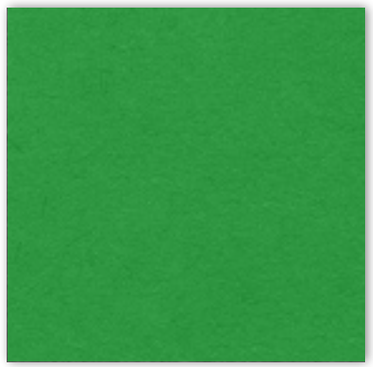
undeformed square patch



patch area

$$A = L^2$$

isotropic deformation



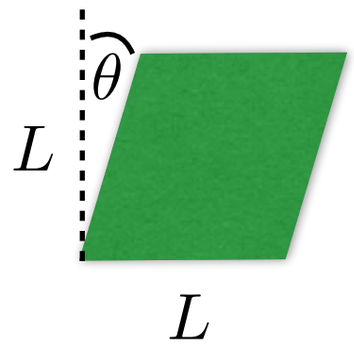
$$\frac{E}{A} = \frac{B}{2}\left(\frac{\Delta A}{A}\right)^2 \approx \frac{B}{2}\left(\frac{2\Delta L}{L}\right)^2$$

bulk modulus

$B \sim 0.2\mathrm{N/m}$

(lipid bilayer)

shear deformation



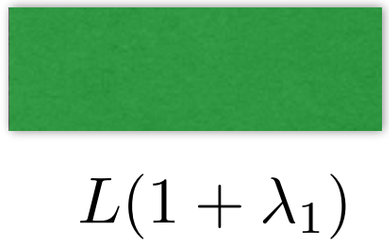
$$\frac{E}{A} = \frac{\mu\theta^2}{2}$$

shear modulus

$\mu \sim 10^{-5}\mathrm{N/m}$

(spectrin network)

anisotropic stretching



$$\frac{E}{A} \approx \frac{B}{2}\left(\lambda_1 + \lambda_2\right)^2 + \frac{\mu}{2}\left(\lambda_1 - \lambda_2\right)^2$$

$\lambda_1, \lambda_2 \ll 1$

(shearing can be interpreted as anisotropic stretching)